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Plane of Nutrition for Dairy Cows

W. H. BROSTER

National Institute for Research in Dairying. University of Reading

EFFICIENCY of the milk production enterprise depends on so many factors that it can be profitable or unprofitable under a variety of conditions, some of them seemingly controversial, even contradictory. Orderly understanding of the pertinent factors and conditions has called for research on the subject from many points of view, some directly, some more remotely connected with the immediate process of milk production. Thus, this article concerns one aspect of one problem only—that of feeding the cow. Concentrates are the most expensive item in the cow's dietary; they are by common knowledge effective in stimulating milk production; they are also usually the marginal input factor. Accordingly, a balance is sought between the use made of them and the resultant effect on milk yield, so that the farmer may obtain the maximum profit. Of course, the final arbiter in any decision regarding plane of nutrition for a particular group of cows is the sum total of local conditions such as stock management, as interpreted in the light of the results of a variety of investigations, not the direct results of feeding experiments alone. The object of this article, however, is to summarize current knowledge of plane of nutrition of dairy cows as based on practical feeding trials and to indicate briefly its economic significance. The importance of the breakdown products formed in the rumen from the ingested feed will not be discussed.

Concentrates *v.* Roughages

Bulky foods—roughages and succulents—are cheaper than concentrates, and it is reasonable to place maximum reliance on these in feeding the cow [1]. With good-quality grassland of high nutrient content and palatability, large yields of milk have been obtained in short-term trials without recourse to concentrated foods. Responses to such additions of concentrates to the ration are likely to be very small and uneconomical [2, 3 and 4]. Riddet and Campbell [5] concluded nevertheless that maximum yield was not likely to be evoked on pasture alone. With decline in quality of grassland, responses to supplementary feeding will increase [6 and 7], and will approach those found with winter roughages. Lactation records of cows on *ad lib.* rations of good quality hay and/or silage compared with similar rations supplemented with concentrates have been examined in a number of American experiments [8, 9 and 36]. Maximum potential yield was not reached on roughages alone. Short-term studies in Great Britain [1, 10 and 11] also show that cows cannot consume sufficient nutrients as roughages to meet maximum demand for milk production. Thus,

one effect of including concentrates in the ration is to surmount this difficulty by extending appetite, and by ensuring that an adequate nutrient concentration exists in the ration as a whole.

Comparisons of roughages and concentrates in terms of total digestible nutrients have favoured concentrates [12 and 13]; in terms of net energy or starch equivalent this advantage is no longer apparent in some experiments [8, 14, 15, 16 and 35] but is still so in others [17 and 18]. This unsettled question does not influence the situation that, for maximum production, concentrates must be included in winter rations. At the same time survey evidence shows that for any given range of yields, the less the dependence on concentrated foods the greater the profit per cow [1 and 19]. The comparative worth of concentrates and roughages is a part of the general problem of the relative values of foods at different planes of nutrition.

Relative Importance of Energy and Protein in Plane of Nutrition

Before discussing any quantitative results of experiments on plane of nutrition it will be convenient here to refer briefly to the relative importance of energy and protein as limiting factors to milk production. The available evidence shows strongly that energy exerts the greater effect over the ranges of intake normally encountered. Such experiments as have been concerned directly with protein requirements have found standard [20] levels to be adequate [21, 22, 23 and 24]. Excess protein had little effect on yield [25, 26, 27 and 28], while reduction below the Woodman standards has been found to penalize yields [29 and 30]. In one experiment [30] the reduction of the crude protein intake of cows giving $2\frac{1}{2}$ gal/day by approximately 0.5 lb/day below Woodman's standards only reduced yields by 1.3 lb/day. This agrees broadly with the estimate quoted from survey data by Orton [31] who found that 1 cwt additional protein equivalent fed to cows induced an increase of 40 gal fat-corrected milk. Since most experiments on the influence of plane of nutrition on milk yield have included standard levels of protein, we can assume that variation in milk yield is due to variation of energy intake.

Long-term Experiments

Several reviews are available [8, 9, 32 and 36] of experiments in which cows were fed contrasting levels of concentrates for the whole of one or more lactation, notably the experiments of Jensen *et al.* [33] and Larsen and Eskedal [34]. All reviewers conclude that the data indicate a declining response in terms of milk yield to successive increments in the plane of nutrition. Further analysis [9] to include maintenance requirements and changes of liveweight in the input-output equation shows that the decline in overall efficiency of food utilization is not so marked as for milk production alone. An example

[33] of the relationships obtained between milk yield and food input is shown in Table 1. Burt [32] tabulated a number of the results in terms of starch equivalent, and these figures show that if cows yielding about 25-35 lb/day were fed 2½ lb starch equivalent/10 lb milk, the response was about 2 lb extra milk/additional lb starch equivalent; at a basal rate of 3½ lb starch equivalent/10 lb milk, the response fell to 1 lb extra milk/additional lb starch equivalent. With milk and concentrates at today's prices, responses only at the lower basal rate of feeding were economical. Yates *et al.* [8], after expressing all cost units in terms of food, concluded that the optimum economic level of nutrient intake was 2.8 lb S.E./10 lb milk for cows giving 2 gal when fed 2.5 lb S.E./10 lb milk.

Survey Investigation

Since survey data are based on lactation yields, it is convenient to discuss them here. Despite the criticisms levelled at this type of investigation, they offer a direct link with farm conditions and provide a cross-check of experimental results. Table 1 shows data by Jawetz [35] relating milk yield and starch equivalent intake. The marginal responses are greater than those quoted by Jensen *et al.* [33]. Part D of Table 1 shows the concentrates needed to raise monthly yields by 5 gal. These are much lower than the anticipated requirements according to long-term experiments. On the other hand, the yields at which these increases are judged to occur are also much lower, suggesting a lower plane of nutrition, although quality of cow may also be involved. The cost of the necessary concentrates would, it was calculated, be less than the value of the extra milk, except when yields were about 900 gal per lactation and milk prices were at their spring minimum. Jawetz [35] also found that high-yielding cows made more economical use of concentrates than did poor-yielding cows. Response curves to extra feeding will vary on this account, and also almost certainly on account of differences of management [34]. Both these factors should be allowed for in analysis, otherwise a biased conclusion could result. In an attempt to study changes of food input/milk output relationships [31] for a number of farms over a period of years, Orton found British and Danish data to be inconclusive and unable to confirm the results of his cross-sectional survey quoted above.

Short-term Experiments

Most short-term trials have included cows in the declining phase of lactation [11, 27, 36, 37, 38, 39, 40 and 41], for periods of 12 weeks at the most. The results show a response of about 1 lb extra milk/additional lb S.E. at a basal rate of 2.0-2.7 lb S.E./10 lb milk. Table 1 quotes the results of a typical experiment. Similar results were obtained in two experiments [23 and 42] on cattle in early lactation. The principal

Table 1

Responses to Additional Concentrates Fed above Maintenance

A. BASED ON LONG-TERM EXPERIMENT (*Jensen* et al. [33] *taken from Burt* [32])

Milk yield/day (lb)	25.8	27.9	29.7	31.5	32.7	33.8	
Lb S.E./10 lb milk	2.5	2.7	3.1	3.5	3.7	4.1	
Lb additional milk/lb additional S.E.	—	1.8	1.0	1.0	1.3	0.6	

B. BASED ON SURVEY OF FARM DATA (*Jawetz* [35])

Milk yield/day (lb)	15.0	16.7	20.0	23.3	26.7	30.0	33.3
Lb S.E./10 lb milk	2.2	2.3	2.4	2.7	3.1	3.5	4.5
Lb additional milk/lb additional S.E.	—	3.6	3.2	2.3	1.7	1.4	0.8

C. BASED ON SHORT-TERM EXPERIMENT (*Holmes* et al. [34])

Milk yield/day (lb)	22.2	23.8	26.0	27.6
Lb S.E./10 lb milk	2.4	3.0	3.5	4.2
Lb additional milk/lb additional S.E.	—	0.8	1.2	0.7

D. CONCENTRATES REQUIRED TO INCREASE MILK YIELD (*Jawetz* [35])

To raise monthly yield gal/cow		Concentrates required/gal	Total costs	Value of 5 gal milk Date	
from	to	(lb)	*s. d.*		*s.*
45	50	4.2	7 6	Jan. - March	17
60	65	5.8	10 8	Apr.- June	11
75	80	6.9	13 3	July - Sept.	13
				Oct. - Dec.	18

Table 2

Results of Experiment [58] on Levels of Concentrates for Dairy Heifers

Treatment	HH	HL	LH	LL
No. of animals per treatment	22	22	22	22
Milk yields (lb) during first 84 days	2,773	2,719	2,731	2,439
Total concentrates (lb) "steaming-up" ration and days 1-84 of lactation	1,689	1,110	1,442	862
Efficiency of conversion of concentrates lb concs./lb milk (days 1-84 of lactation)	0.61	0.41	0.53	0.35
Lb additional concs./lb additional milk. Days 1-84	2.48	0.88	1.98	—
Milk yield (lb) during 305 days	8,220	8,171	8,089	6,750
Lb additional concs./lb additional milk. Days 1-305	0.87	0.49	0.77	—
Profit or loss over LL. Period 1-84 days	−£5 7*s.* 9*d.*	+£1 2*s.* 0*d.*	−£2 18*s.* 0*d.*	—
Profit over LL. Period 1-305 days	£2 6*s.* 9*d.*	£8 19*s.* 0*d.*	£3 16*s.* 0*d.*	—
Time (days) to reach peak yield	31.5	25.2	25.0	19.0
Persistency (days)—time for yield to decline to half peak yield	296	278	278	257
Solids-not-fat percentage. Days 1- 84	8.93	8.97	8.92	8.93
Solids-not-fat percentage. Days 1-305	9.02	9.04	8.97	8.98
Butterfat percentage. Days 1- 84	3.28	3.65	3.30	3.56
Butterfat percentage. Days 1-305	3.38	3.69	3.48	3.69

features of this conclusion are that the responses are much lower than those found in long-term experiments and in surveys, and they are almost invariably uneconomic. Because of the small treatment differences likely to be encountered, short-term trials have usually been based on relatively elaborate statistical designs in which only the immediate effects of the treatments were studied. But carry-over effects were sometimes recorded [36 and 63]. Furthermore, the brevity of the experimental periods has not allowed critical investigation of liveweight changes on the various treatments. Occasionally, increased rates of liveweight gain have been observed on the higher levels of feeding [36 and 41], but the significance of such changes in weight to later production has not been established. Burt [39 and 40] also recorded the possibility that high-yielding cows made better use of supplements than low-yielding cows.

Thus the overall picture derived from these investigations is one of a broad measure of agreement between experiments of the same type, and some disagreement between the general results of different methods of investigations as to the size and monetary value of the increase in yield induced by extra feeding. It is the cause of this disagreement which now requires elucidation.

Experiments on Preparation of the Cow for Lactation

More recently attention in experimental work has been directed to the importance of preparation of the cow for lactation, i.e., the significance of level of feeding immediately before and after calving in control of lactation performance. Work published in New Zealand [43, 44 and 45] and Great Britain [73] showed that short periods of undernutrition immediately after calving not only depressed yield concurrently but over the whole lactation as well; the treatments thus influenced yield after they had ceased. Differences of yield occurred between cows in mid-lactation, ostensibly on the same standard of nutrition. An initial financial loss from feeding 6 lb concentrates per day for 8 weeks was converted to a profit over the lactation [45]. Other effects of underfeeding in early lactation were: quicker attainment of peak yield, reduced persistency and a greater tendency to put on weight in mid-lactation.

The strong advocacy of high-level feeding in late pregnancy [46] has received support from a number of experiments in which supplementary rations of concentrates were fed at this time [47, 48, 49, 50 and 51]. Occasionally, no benefit at all or only very small increases in yield have been observed [52 and 53], or heifers have been affected but not cows [48]. New Zealand experiments [54, 55, 56 and 57] show that reduction of the pre-calving ration, usually roughages in that country, to subnormal levels penalized subsequent milk yield. The results of an attempt to provide a "steaming-up" ration from roughage [49] were indecisive as the stock were unable to consume adequate amounts

of the supplements. In the above experiments, it was not always possible to judge how long the benefit from "steaming-up" lasted. On some occasions, twelve weeks has appeared to be the limit, on others the full lactation has been influenced. Even when judged over only the first three months of lactation, the response to "steaming-up" has usually been considerably greater than that obtained from high-level feeding in lactation and reached 2 lb of milk/additional lb S.E. [49].

The economic advantages of "steaming-up" are apparent. The exact mode of action is not readily explained, nor is information available about a number of aspects of the phenomenon such as which nutrients in the ration bring about this effect, or the quantities of food required.

In two experiments [58 and 59] the problem of the interaction of levels of feeding before and after calving have been considered.

An experiment at the National Institute for Research in Dairying [58] was designed to examine further the effects of "steaming-up" and level of feeding in early lactation on yield and composition of milk of dairy heifers during the full lactation. Shorthorn and Friesian heifers calving during the autumn and early winter of the three seasons 1954-7 were used. A 2×2 factorial design was used with two levels of "steaming-up" and two levels of feeding in early lactation, i.e., with four treatments in all. The levels of "steaming-up" rations were:

High 2 cwt "balanced" concentrates spread over the last 3 weeks of pregnancy.
Low ½ cwt "balanced" concentrates spread over the last 2 weeks of pregnancy.

The levels of lactation feeding were:

High 5 lb concs./gallon during the first 84 days of lactation.
Low 3 lb concs./gallon during the first 84 days of lactation.

After this period all heifers were treated alike, receiving 4 lb/gallon during the winter, and an appropriate allowance according to estimated quality of the grassland during the grazing season. Treatments may be connotated as HH, HL, LH, LL. The first letter represents level of "steaming-up", the second the level of lactation feeding, with "H"=High level and "L"=Low level.

The results are summarized in Table 2, on p. 5, using the above connotation. Over the first 84 days HH, HL and LH all outyielded LL, but showed little difference amongst themselves. When the concentrates consumed are considered, HL showed an overall rate of conversion far superior to those of HH and LH and produced extra milk with but little decline in efficiency of conversion compared to LL. More important is the marked residual effect of the treatment as seen from the 305-day yields. The advantage over the first 84 days was quadrupled over the lactation. The extra milk produced by HH, HL, LH earned the cows more concentrates; the maximum quantities these could have been were 1,070, 492, 980 lb respectively for the 305-day lactation—based on treatment levels for the first 84 days and

4 lb/gallon for the remainder of the lactation. Again, HL produced the extra milk at a rate of 0.4 lb concentrates/1 lb milk—i.e., at the standard rate [20].

The estimated financial returns based on milk value less food costs show that only HL produced a profit over the first 84 days of lactation, but that all forms of supplementation were profitable when assessed on the basis of the whole lactation.

"Steaming-up" induced appreciable increase in yield only when level of feeding was not excessively high during lactation, therefore high "steaming-up" combined with high lactation feeding was wasteful of concentrates. Whilst either high "steaming-up" or high lactation feeding alone produced equal results, high "steaming-up" required a smaller amount of concentrates ($2\frac{1}{4}$ cwt *v.* $5\frac{1}{4}$ cwt). The comparison of LH and LL showed that the response to additional feeding in early lactation approximated to 1 lb milk/lb extra S.E., i.e., a value similar to that obtained with cows in mid-lactation. The link between the low and uneconomical responses to additional feeding over a short period in mid-lactation, and the more economical benefits derived from high level feeding throughout the lactation appears to lie, in part at least, in the residual effects of adequate preparation for lactation. The two sets of results are not contradictory therefore. It is interesting to note that the extra milk produced by LH over LL, i.e., 1,339 lb would require—at the rate of 1 lb S.E./lb milk—about 1 ton of concentrates. In this experiment it was produced by rather less than $\frac{1}{2}$ ton, or 2 lb milk/additional lb S.E.

Increases in butterfat percentage as a result of "steaming-up" have been recorded [45, 47 and 62]; "steaming-up" had no effect *per se* on milk composition in the N.I.R.D. experiment [54] although high lactation feeding was associated with a reduction in butterfat percentage. Thus the treatment HL combined high yield and high butterfat percentage. A similar effect was recorded many years ago [60 and 61], but as yet no completely satisfactory explanation is forthcoming. It may be coupled with an adverse effect on liveweight from this treatment in early lactation [58]. However, this effect had been eliminated by time of second calving. The decline in butterfat percentage coupled with high lactation feeding is not uncommon in itself [63], but frequently no effects are recorded when plane of nutrition is changed [38, 39 and 40]. Excluded from this is the influence of changes from winter rations to pasture [64] and the use of low roughage rations [65]. Variation of protein intake alone has little or no effect on butterfat content [65 and 66].

Time to reach peak yield was delayed by the supplementary feeding, and persistency of milk yield was increased, a result in harmony with the results of experiments on under feeding in early lactation [43, 44 and 45].

Another experiment, by Patchell [59], included treatments corres-

ponding to HH, HL and LL above and was conducted on heifers and cows, with rations based on grass and roughages. The results are broadly similar to those above, although a much smaller response was obtained in the first than in the second year of the experiment. In the N.I.R.D. experiment the results were uniform for each of the two breeds and in each of the three years that the experiment was run. The greater variability of responses at grass are illustrated by these two sets of results.

Plane of Nutrition and Solids-not-fat Percentage

The final point to be dealt with briefly is the influence of plane of nutrition on solids-not-fat percentage in the milk. This appears to be affected in the same way as milk yield. Severe depression of energy intake (experimentally up to 30 per cent of Woodman's standards) can reduce s-n-f percentage by as much as 0.4 [67, 68, 69 and 70]. Conversely, increases in energy intake to 125 per cent of Woodman's standards have usually increased s-n-f percentage by 0.1-0.2 [38, 39, 40, 66, 70 and 71], a much smaller effect than that induced by reduction of energy intake. Decreases of protein also reduced s-n-f percentage [68 and 69]; increases of protein have very little effect [27 and 30]. A summary of New Zealand work on s.n.f [70] shows that whereas cows react to the influence of plane of nutrition, heifers do not. No effect on s-n-f percentage of the milk of heifers was recorded in the N.I.R.D. experiment [58], although Burt [40] did find such an effect in heifers.

Summary

In summarizing the above experiments, there are a number of points to be stressed. Responses to plane of nutrition in the dairy cow are governed by the law of diminishing returns both for yield and s-n-f percentage. This effect has been observed in all the types of investigation discussed. The problem now becomes the calibration of the response curve but it is in relation to this aspect of the problem that current knowledge is limited. It has been adequately demonstrated that cows in mid-lactation produce approximately 1 lb extra milk/additional lb S.E. when their general plane of nutrition includes over approximately 2 lb S.E./10 lb milk produced. This response is much lower than would be necessary to be economical. At lower levels of feeding a greater response may be anticipated. The significance of differences between cows in efficiency of conversion of food in relation to plane of nutrition has not yet been fully investigated, nor have such limiting factors as capacity to ingest food in very large quantities.

Cows fed contrasting planes of nutrition from calving show much larger responses per additional unit S.E. than that recorded in short-term experiments. In relation to this apparent discrepancy, evidence

is now available on the importance of preparation of the cow for lactation both immediately before and immediately after calving. Milk yield throughout lactation is influenced by plane of nutrition before calving, thus the effects of the treatment as such occur after the treatment has ceased. Similarly, level of feeding in the period immediately after calving influences current yield and lactation performance. Thus both these types of treatment have a marked residual or carry-over effect. It appears that both nutritional and physiological factors are involved. It may be noted that the effects of high planes of nutrition during these periods were not fully additive.

Milk production as a function of food input must be studied in terms of the lactation as a whole; not solely as an instantaneous input/output relationship. Indeed capacity to produce milk is now being related in experimental studies to plane of nutrition and to type of ration used during the growth period. The further advance of knowledge of rumen biology and function is awaited with interest; it must not be allowed to develop in a "nutritional vacuum" through lack of practical application. The diversity of experiments found necessary to study utilization of urea for example [72] illustrates this better than any of the writer's philosophizing.

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Evaluation and Formulation of Poultry Diets

W. BOLTON

A.R.C. Poultry Research Centre, Edinburgh

ONE HUNDRED YEARS AGO the feeding of poultry was based only on crude observations, as the following extract from Meall (1854) shows:

> It will be found most advantageous to allow the heaviest and best (*corn*), which shows itself not only in the size and flesh of the fowls, but also in the eggs. Barley and wheat are the great dependence for poultry: the heaviest oats will keep them, it is true, but neither go so far as other corn, nor agree so well with the chickens, being apt to scour them . . . they should be well supplied with greenfood, without which they will not enjoy good health, the flesh being not so firm, and the eggs poor, the yolks being of a pale sickly colour.

Meall [6] goes on to recommend feeding "wholesome" kitchen refuse "occasionally", but in small quantities and points out the need for some "animal food". For chicks he recommends bread soaked in ale (but not gin), "eggs boiled hard and cut up very small", and the avoidance of all "vegetables, sloppy or watery food, such as potatoes."

It is obvious that these observations were sound, and that the dietary regime was as adequate as the foods available permitted. But such diets could not be assessed in chemical terms, and, indeed, chemistry then was itself inadequate.

The first advance came in 1860, when Henneberg and Stohmann [4] published their method for assessing carbohydrates as crude fibre and nitrogen-free extractives (NFE). The partition was based on work with steers, and although the authors fully realized that some of the NFE was not digested and some of the crude fibre was digested, their experiments showed that the indigestible NFE was approximately equal to the digestible crude fibre.

It is important to note that the chemical evaluation was made of the indigestible carbohydrate and that digestible was obtained by difference. Valuable though this partition has been for work with ruminants, it has its disadvantages. Norman [7] found that he could recover only 4–40 per cent of the lignin in the crude fibre, while Woodman & Stewart [9] found that digestibility also depends upon the distribution of the lignin, so that even a small increase in the lignin content could markedly reduce the digestibility. Hence, variations in digestibility even by steers could not always be forecast by analysis.

Studies with Steers

The final arbiter of the diet is, of course, the animal, and the next advances came from balance studies with steers, carried out by Kellner [5] in Germany and Armsby [1] in the U.S.A., around the turn of the century. Kellner measured the intakes of digestible protein, oil and carbohydrates, the amounts of carbon dioxide and methane liberated by the animal and the amounts of flesh and fat produced. His procedure was first to feed just sufficient food so that the steer neither lost nor gained weight, and then to add (say) 2 lb starch to the daily diet. From the carbon balance this was found to produce 0.5 lb fat. The study was extended to cover the other constitutents of the diet, protein and fat; the fat being sub-divided according to its origin. He then fed natural foods, and in almost every instance the amount of fat produced was less than that predicted, the exceptions being foods such as maize where the fat produced equalled that predicted. In no case was the prediction lower. The discrepancy, which he concluded was due to the work of digestion and in an amount inversely proportional to the crude fibre content, was then formulated into his value or V number. From this basis Kellner (1905) produced his table of Starch Equivalents, which are the number of lb starch which will produce in the steer the same weight of fat as that produced by 100 lb of the food.

Armsby tackled the problem from a completely different angle. He measured the actual heat given out by steers from the consumption of certain quantities of foods. He determined the gross heat produced when the food was completely burned, and also the gross heat of combustion of the excretory products. From these he calculated the amount of energy or heat-producing value of the food to the animal. This is now termed the metabolizable energy. Armsby then proceeded to use the animal calorimeter to find out the amount of net energy in the food, i.e., the metabolizable energy minus the energy produced by digestive processes, whether by the actual work of digestion or by the marked rise in heat evolution which always accompanies the intake of food, the specific dynamic action. His results were summarized in a book published in 1917.

Kellner and Armsby thus arrived at the same goal by two different routes, and if Kellner's Starch Equivalents are multiplied by 1.071

they are converted into Armsby's Net Energy Values in therms per 100 lb.

American and U.K. Experiments

It is of interest to note that, about twenty-five years later, the application of these basic principles to poultry also proceeded at the same time on both sides of the Atlantic Ocean, but again along different lines. In the U.K., Halnan [3] applied the Starch Equivalent concept to poultry foods, and from his own results was able to produce a table of Starch Equivalents for poultry which he included in his bulletin first issued in 1930. However, he adopted the NFE/crude fibre partition for the carbohydrates, and was not therefore, able to forecast the starch equivalent from chemical analysis, as had Kellner. In the U.S.A., Fraps [2] produced a table of Productive Energy Values which were really net energy for growth, and not productive energy as we normally understand it. Both systems deservedly have been used widely in the respective countries, but both have disadvantages. In each case the data are for the samples of food actually used by the investigator, and for Frap's data, Titus [8] has pointed out that some of his analyses are not typical of the foods in use today. In neither case is it possible to evaluate a complete diet unless the formula is known, and in both cases the chemical analysis of the food is based on the NFE/crude fibre partition, which was originally designed for the fattening steer.

It was obvious at this stage that further progress could only be made with great difficulty unless a new chemical basis of evaluation was adopted, but it was not clear whether this should aim at measuring the carbohydrate not digested by the fowl, *à la* Henneberg & Stohmann, or measuring that digested.

A New Chemical Basis of Evaluation

The digestibilities of more chemically defined fractions of the carbohydrate complex were therefore determined in a series of experiments at the Poultry Research Centre. These fractions were: sugars, dextrins +starches, pentosans, cellulose and lignin. This series comprised fifteen foods, eleven of them single foods and the other four complete diets, in which the digestible carbohydrate contents ranged from 19 per cent to 66 per cent. It was found that the sugars and dextrins+starches were completely digested, the cellulose and lignin were indigestible and that, while some of the pentosan was digested, this only became important compared to the total digestible carbohydrate in a few foods, the most notable being the wheat offals.

Following the precedent set by the Ministry of Food in 1943 for the evaluation of human diets, the sugar and dextrin+starch, expressed as percentage starch by multiplying the sugar percentage by 0.91, was termed the "available carbohydrate". Statistical examination showed

that there was a very highly significant correlation (coefficient +0.989—a perfect correlation would be +1.000) between the available and digestible carbohydrates, and that:

$$\text{Digestible Carbohydrate} = \text{Available Carbohydrate} + 4.9$$

In this study the sugars and dextrins+starches were estimated separately, and the method was too time-consuming for adoption as a routine measure. The method has now been simplified, and in time taken per estimation compares favourably with the crude fibre determination. Details will be published in the near future.

This approach differs fundamentally from that adopted previously. Instead of estimating the indigestible component chemically and the digestible by difference, the digestible is estimated chemically and the indigestible by difference. Thus not only does a positive replace a derived value, but the cumulative errors of all the analyses on the food are transferred to the less important component. Moreover, it is equally applicable to single foods and to complete diets.

Continuing Experiments in Digestibility

At this stage it was necessary to find out whether anything comparable with Kellner's V numbers would be necessary, so a further experiment was initiated. A group of hens was fed on a highly digestible diet (indigestible organic matter content 14 per cent) and another group on a more indigestible diet (indigestible organic matter content 27 per cent). For other reasons the experiment lasted two years and the cogent results for the pullet year are summarized in Table 1 below.

Table 1

Comparison of High and Low Energy Diets Fed to Pullets

	High Energy Diet	*Low Energy Diet*
Food/bird/day (g)	103	126
Digestible Protein/day (g)	14.5	14.4
N.P.D.E.*/day (g)	57.4	56.2
Eggs/bird/year	243	248
Indigestible Organic Matter (%)	13.7	27.4

*N.P.D.E. = Non-protein Digestible Energy.

It will be noted that the indigestible matter eaten daily was 14g for the group on a high energy diet and 35g for the low energy diet. Yet despite this great difference, the intakes of digestible protein and energy were the same per day, as was the egg production. This result indicated that V numbers were not necessary for poultry diets since the work of digestion is not proportional to the indigestible organic matter intake. When this experiment was in progress the simple method for the estimation of available carbohydrate was only in the process of development, and this datum could not, therefore, be determined on these diets. The interim results from an experiment at present in

progress, set out in Table 2 below, show that the " digestible " carbohydrate estimated by available carbohydrate+4.9 agrees closely with that from biological experimentation for replicate mixes of the same diet, and the data in Table 3 indicate that the formula is applicable to diets for young stock except where high levels of supplemental fat are added.

Table 2

Comparison of Digestible Carbohydrate and Available Carbohydrate in Replicate Mixes of the Same Formula

Mix No.	1	2	3	4	5	6	7	8	Means
Dig. Carb. ...	38.2	39.4	40.0	41.8	42.1	43.7	39.4	40.5	40.6
AC+4.9	38.1	40.1	40.2	39.5	39.8	40.6	39.8	42.4	40.1

Table 3

Comparison of Digestible and Available Carbohydrate in Different Formulae

	Dig. Carb.	AC+4.9
Chick Mash (14-21 days)	35.0	38.0
,, ,, (35-42 days)	35.5	38.0
,, ,, (0-9 weeks)	43.4	44.3
,, ,, (0-10 weeks) . . . . . . supplemented with 10% beef dripping	*29.5	*35.3
Growers Mash (10 weeks)	42.6	44.0
Layers Mash 1.	49.1	46.1
2.	31.8	30.1
3.	43.3	43.4
Means (excluding *)	40.1	40.6

The series of experiments also showed that the bird was able to digest about 87 per cent of both the protein and oil in normal diets, although the digestibility of the oil was reduced to 80 per cent when 10 per cent beef dripping was incorporated in a chick mash. It is, therefore, now possible to estimate the digestible protein, oil and carbohydrate contents of a single food or a complete diet with a reasonable degree of accuracy by purely chemical methods, viz.:

Digestible protein $=0.87\times$ crude protein.
Digestible oil $=0.87\times$ ether extract.
Digestible carbohydrate = available carbohydrate + 4.9.

It will be noted that since this scheme gives the digestible nutrients, it also permits those indigestible to be estimated. The indigestible organic matter forms the bulk which is necessary to maintain the tone of the gut. For young chickens about 13 per cent is adequate, any excess may tend to reduce the intake of digestible food. Older fowls have given good results on levels ranging from 13 to 29 per cent but between 15 and 20 per cent would seem to be the more usual range.

Nutritive Ratios

The Nutritive Ratio, in its simplified form, is:

$$\frac{\text{Digestible Carbohydrate} + 2.25 \times \text{Digestible Oil}}{\text{Digestible Protein}}$$

The numerator of this ratio is a measure of the non-protein digestible energy (N.P.D.E.) of a diet, and it will be seen that both the N.P.D.E. and digestible protein can be estimated in the laboratory.

Now it is becoming increasingly obvious that it is the ratio of energy to protein that is important, rather than the actual protein level, and work on fat supplemented diets has emphasized this. Moreover, it has been known since at least Meall's time that wheat has a higher energy value than oats; based on the N.P.D.E., if maize is 100, then wheat is 90, barley 80 and oats 70, and these four grains form the greater part of the poultry diet. Hence a level of protein adequate for a diet made up mainly of maize would be excessive for one largely oats. Once the nutritive ratio is known for different classes of stock, if the N.P.D.E. is known then the required protein level can be calculated.

It is apparent that recommended nutritive ratios are of more value than recommended levels of protein. Recent work suggests that the nutritive ratio should be 2.5 to 1 for the first two weeks, gradually widening out to 4 to 1 for growers at 10 weeks old. For broilers, a ratio of about 3.2 to 1 after the first fortnight has given good results. Layers and breeders have laid at the rate of 245 eggs per year on a ratio of 3.95 to 1 whether the diet be relatively rich or poor in energy.

The demand for protein is in reality a demand for the essential amino-acids in the correct proportions and amounts for the total nitrogen intake. It is not yet practicable for a complete amino-acid analysis to be carried out on every sample of every food, nor even on complete diets. Tables of amino-acid compositions of foods have been compiled, but it must be borne in mind that differences do exist between samples of the same food. At the present stage of our knowledge it is sufficient to ensure that the diet is adequate as calculated from tables. In my own experience the amino-acids most likely to be deficient are lysine and methionine+cystine.

With regard to the accessory food factors, only a few vitamins and minerals are likely to be deficient in U.K. diets. These are vitamin A, D_3, E, B_{12}, riboflavin, choline and nicotinic acid among the vitamins and calcium, phosphorus, manganese, iodine and chloride (or common salt) of the minerals. Calcium and phosphorus must be regarded as major nutrients and levels of 1 per cent calcium with 0.6 per cent total phosphorus (including 0.45 per cent inorganic phosphorus) should be supplied for non-laying birds, and 2.5 per cent calcium with 0.8 per cent total phosphorus (including 0.6 per cent inorganic phosphorus) for layers.

The others should be present in adequate, but not excessive, amounts.

While they should more properly be allied to the N.P.D.E. content, a substantial margin of safety is allowed so that the possibility of a deficiency will only arise when diets rich in maize are supplemented by high levels of fat. In these cases the levels of the accessory food factors should be increased in proportion to the energy content of the diet. This can be attained partly through the extra protein needed and partly through vitamin/mineral supplements.

Summary

1. The development of the evaluation of poultry diets is briefly reviewed.

2. It is demonstrated that the available carbohydrate (sugar+starch expressed as percentage starch) is closely related to the digestible carbohydrate; for diets which are not supplemented by high levels of fat the digestible carbohydrate is equal to the available carbohydrate plus 4.9.

3. Except when high levels of supplemental fat are added to diets, about 87 per cent of the crude protein and fat are digested, hence the non-protein digestible energy (digestible carbohydrate+2.25×digestible fat), the digestible protein, and the nutritive ratio can be estimated from chemical determinations.

4. The formulation of poultry diets using this new basis is briefly described.

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Performance and Progeny Testing of Beef Bulls

I. L. MASON

A.R.C. Unit of Animal Genetics, Edinburgh

WE HEAR a great deal about progeny testing these days. How much of this is ballyhoo and how much is new and useful to the farmer? It can be argued that these islands produced some of the world's finest beef breeds before anyone started to talk about progeny testing. Judging by eye alone individual pedigree breeders have evolved those Hereford, Aberdeen-Angus and Beef Shorthorn cattle which are sought all over the world. What has the scientist to suggest which the breeder has not already done or could do by using the same methods in the future?

It is clear at the outset that as improvement progresses it gets progressively more difficult. Here the scientist can help by providing accurate objective measures of the small differences on which future selection must be based. But, in addition to this, two changed circumstances now make the geneticist's help both desirable and possible.

To begin with, the market demand has changed from a large fat beast to a smaller and much leaner one. The butcher is still looking for an animal with a high proportion of the fleshy parts of the rump and back; these form the roasts and steaks for which the customer is prepared to pay highly. At the same time he wants a carcass with the minimum amount of wasteful fat, yet sufficiently finished to have enough marbling fat to give a tender meat.

How the Scientist Can Help

To a certain extent this desirable animal can be obtained by appropriate feeding and management and can be identified on the hoof. But the fine points of the carcass can only be observed in the dead animal and can only be reproduced by selecting the right sort of breeding animals —particularly bulls. Since one cannot select a breeding bull on the basis of his carcass one can only look at the carcasses of his offspring, and it is the selection of a bull on the basis of their carcass qualities which constitutes a "progeny test".

It must be emphasized that a progeny test is only justified when bulls are to be selected on the basis of carcass qualities. If selection is based on external characters alone—rate of growth, conformation and so on—only the bull need be studied. Such a study—known as a "bull performance test"—will supply more information about these points than would a study of a limited group of progeny.

The second circumstance which makes it possible for the geneticist to help in the selection of beef bulls is the widespread use of artificial insemination by which means bulls sire many offspring spread over

many different herds. They can be compared on the basis of these offspring much more accurately than if each bull were used in a single herd, since differences between progeny groups would include differences between herds, and a bull might appear superior not because he was genetically better but because he was being used in a better-managed herd.

The extensive use of A.I. also means that each bull will have much more influence—for good or for bad—than if he was used in natural service. It is therefore most important to make sure that such bulls are selected in the best possible manner. The scientist cannot promise any rapid spectacular results, but he can suggest how the traditional breeding methods may be adapted to the changed circumstances. In particular, he can suggest how a scheme of performance and progeny testing can be fitted into an A.I. system and used to select the best beef bulls.

Performance Test

Progeny testing is only necessary for carcass characters and, in any case, it can only be applied to a sample of the bulls actually born. A preliminary selection should therefore be made on the basis of the bull's own performance and only bulls passing through this sieve would be sent to an A.I. Centre and progeny tested.

For a performance test, bulls have to be compared under identical conditions. If they were suckling their dams and on different farms it would not be clear how much of any difference in growth rate was due to the different milk yield of their dams, how much was due to environmental differences between farms, and how much to the genetical differences between bulls; only the last can be passed on to their offspring.

Three pilot beef bull performance tests are already in operation in this country:

1. The Ministry of Agriculture is testing Hereford bulls at Rosemaund, Hereford.
2. The British Oil and Cake Mills Ltd. are testing Aberdeen-Angus and Beef Shorthorn bulls at Selby, Yorks.
3. The North of Scotland Agricultural College is testing Beef Shorthorns at Aberdeen.

Bull calves born during the same month are brought at a few weeks of age to the Performance Testing Station and reared on the bucket. If they are suckled on nurse cows it is necessary to estimate their consumption of milk and, if necessary, equalize it. All bulls are treated exactly alike.

In these tests the three items measured are: rate of liveweight gain, efficiency of food utilization (i.e., lb liveweight gain per lb food consumed), and beef conformation.

At 10-12 months the best bulls will be selected on the basis of these three characters. No attention should be given to fancy points such as

colour, markings, or horn shape. We are breeding bulls for beef production, not for a beauty competition.

Progeny Test

The selected bulls will be taken to an A.I. centre for progeny testing. They will be used intensively for a few weeks until each has served about twice as many cows as progeny are desired per bull (or about three times as many if only steer progeny are used). These inseminations will be in herds whose owners agree to co-operate by making the get available to the testing authority.

It is preferable for all cows to be the same breed, e.g., all Friesians, all Ayrshires or all Dairy Shorthorns. If a mixed population of cows were used it would be essential that each type of cow be represented equally among the dams of each progeny group.

The bulls should then be stood down to await the results of the progeny test.

About 10 progeny from each bull will be collected soon after birth and taken to a Progeny Testing Station. At the Station it is most important that the calves should not be separated into groups according to their sire. This would introduce differences between groups quite unconnected with any possible differences between sires. For instance, one group might by chance be in draughtier accommodation or on inferior grazing. Or an infection might occur in one group but not spread to the others. If separation into batches is necessary then it should be, for instance, according to date of birth, and each bull should be equally represented in each batch.

The calves will be reared under standard conditions and observations made on growth, feed consumption and conformation. These will serve to confirm the observations made on the bulls themselves, i.e., they will demonstrate the degree to which these characters are inherited.

The steers will all be slaughtered at the same weight, age, or finish. The same *finish* is difficult to determine accurately and an attempt to use this criterion might well lead to carcasses varying in both age, weight, and finish, and therefore very difficult to compare. The same *weight* is probably most satisfactory from the producer's point of view. The same *age* is the easiest to determine accurately and since this would facilitate the running of the station it will probably be the criterion used.

To get results quickly, and thus keep for the minimum time the bulls which will be discarded as a result of the test, the younger the age of slaughter the better. Baby beef at 12-15 months would be ideal for this purpose. If the bulls were first used at a year old the results of their progeny test would then be available by the time they are three years old.

The best bull or bulls will be retained for extensive use in the A.I. systems and those which fail the test will be discarded. New young bulls for performance testing should be chosen from the progeny of

bulls which have done exceptionally well in previous progeny tests. It is a waste of time and money to test a bull elaborately if he is not adequately used after he is proved, and this means using him to breed bulls for testing as well as to breed commercial slaughter stock.

Carcass Characters

It is not possible to detail at this stage exactly what observations will be made on the carcass. It depends on market demand, on the system of carcass judging already used in the trade or by the Government, and on the facilities available for examining large numbers of carcasses. Briefly what we want to know is as follows:

1. Composition in terms of flesh, fat and bone;
2. Proportion of high-priced cuts;
3. Distribution of fat—subcutaneous, intermuscular, intra-muscular (marbling), suet, and abdominal;
4. Quality of lean meat—flavour and tenderness.

A complete dissection of each carcass is too expensive and laborious. Eye appraisal alone is not sufficiently exact. Something intermediate will probably be feasible.

Figures are much more useful than descriptions. Grading scores can be used provided they are based on a quantitative character (e.g., amount of marbling or firmness of fat) and not on subjective estimation of quality. A "good-medium-poor" type of assessment is useless because the poor animals may be down-graded either because they are, for instance, too fat or because they are not fat enough.

Each bull will be scored according to the average value of the carcasses of his progeny.

Selection for the A.I. Stud

It is impossible to be dogmatic in a scheme of this sort. The limiting factor is the accommodation available for performance testing and for progeny testing. Let us suppose that two bulls of a breed are required to join the A.I. stud each year. If one hundred places are available at the Progeny Testing Station, then it is probably most efficient to test about fourteen bulls with seven offspring per bull. These fourteen bulls would be selected from among those reared at the Performance Testing Station. At least fifty should be reared to get a reasonable choice among them of the best fourteen.

Before holding up your hands in horror at the thought of rearing fifty or more bulls in order to discard forty-eight, bear in mind that the effect of A.I. is to use one or two bulls where fifty were used before. To get the full benefit from A.I. it is surely worth taking considerable trouble to ensure that the few bulls used are the best of the fifty. This scheme envisages a two-phase selection in which about half the selection is done at 10 months and the rest at about 3 years of age (or later).

The basis of any performance or progeny testing scheme must be a comparison. It means nothing to say that this is a good bull because he has grown at the rate of 2 lb per day or because his daughters averaged 1,000 gal milk. The absolute figures depend on the conditions of feeding and management and other bulls under the same conditions might have done even better.

I have outlined a scheme for selecting the two best bulls out of fifty by comparisons between bulls at the same Performance Testing Station in the same year, and between bulls' progeny at the same Progeny Testing Station in the same year. If there are several progeny testing stations, bulls tested at one cannot be compared directly with bulls tested at another. It would be necessary to distribute progeny over all stations so that each bull had the same number at each. Then each bull would, on average, be tested under the same conditions and they could be fairly compared.

On-farm Progeny Test

Theoretically, an equally accurate test of A.I. beef bulls could be organized on the same times as the R.B.V. or Contemporary Comparison method of testing dairy bulls. But its operation would depend on the establishment of a beef recording system analogous to National Milk Records. Beef calves by different bulls would have to be marked, weighed and measured on the farm and then followed through to slaughter. It would only be possible to compare bulls on the basis of calves born and reared contemporaneously on the same farm and likewise fattened and slaughtered in the same batch and season. Using this method, more progeny per bull would be necessary to get a test of the same accuracy as a station test, but also more would be available. It would be excellent to use both methods and compare results.

An on-farm test of a farmer's own bulls is quite easy to arrange provided that:

1. the cows are randomized among bulls;
2. the cows are all run together after service;
3. the calves are marked; and
4. the progeny are fattened together either on the farm of breeding or on another.

But such a test would give information whose interest would be limited to the farmer himself. I am glad to be associated with a pioneer test of this sort which the N.A.A.S. is running in Northumberland.

Conclusions

These are the general principles of an integrated breeding system, but many variations are possible. In the progeny testing, for instance, some may doubt whether the same bull is best for the production of baby beef as for the production of 2½-3-year-old steers off grass. It would be possible to divide each progeny group into two and rear six

intensively in a station to slaughter at one year, while the other six are kept on grass and slaughtered as mature steers. In time it would be possible to see what connection there was between the evaluation of the bulls on the two systems.

To set up a complete system such as I describe takes time. In the meantime progeny testing is getting a trial run based on the bulls actually in use at the moment. The Ministry is progeny testing Hereford bulls on the basis of crossbred steers out of Friesian cows. In co-operation with several other Institutions I am running a progeny test of Friesian A.I. bulls. Work such as this should help to ensure that our beef breeds maintain their high reputation, despite changing market demands and increased competition.

Precision Drilling Swedes

E. I. PRYTHERCH

National Agricultural Advisory Service, Wales

SPACED SEEDING of swedes is a new technique which is becoming successfully established in the traditional root-growing areas. Using precision seeders for this crop is an outcome of the development in sugar-beet growing in which the initial success in sowing single seeds was achieved. The practice reduces the usual high labour costs of cultivation, and also virtually eliminates singling, which usually clashes with other urgent work on the farm such as haymaking. The braird consists of single plants which will not grow into the tangled mass that occurs with the normal method of sowing when singling is delayed. Furthermore, precision drilling enables the whole crop to be sown at any one time, as it is unnecessary to stagger the sowing date to avoid plants coming into the singling stage of growth at the same time.

The success of this technique is dependent on the following:

Adequate and Timely Cultivations

Preparation of the soil by autumn ploughing is traditional in the higher rainfall areas. The stubble is skim ploughed (3-4 in. deep) in the autumn, and cultivated and/or harrowed to encourage the germination of weed seeds. On the medium to heavy soils, "utility" ploughing should follow as opposed to "digger" work on the lighter land. This is important as the crested furrow means more exposure of soil to frost, and a frost mould is always the best tilth. When treated in this way, the soil does not run together or set as does the "forced" tilth which is produced by hurried cultivations just a few days before sowing. On light land the main benefit of earlier cultivations is a substantial reduction in weed population.

Subsequent treatment of fallowed land in the spring is related to the type of soil. On the heavier soils, cultivations must be shallow to preserve the frost mould and to avoid bringing raw soil, with its content of viable weed seed, to the surface. A further ploughing would normally be a disadvantage. The shallow cultivations which are necessary are usually effected by properly adjusted, spring-tined cultivators and harrows, but a thistle bar attached to the rear tines of a cultivator is also an excellent tool for stirring the shallow tilth. Tap-rooted weeds are either brought to the surface or cut by these methods, and weed seedlings are destroyed. On the other hand, a further light ploughing before sowing is an advantage on light land, as it not only eliminates weed seedlings which have germinated after spring cultivations, but also creates satisfactory tilth conditions for sowing. The value of

appropriate cultivations must not be overlooked, since complete mechanization of the crop depends greatly on a weed-free braird.

"Ridging up" is usually practised in the higher rainfall areas, mainly because it provides better drainage conditions. Other advantages include greater freedom from stones on the ridge surface which is needed for the satisfactory use of the drill, good steerage for inter-row cultivators on sloping fields and greater ease of lifting where mechanical harvesting is practised.

On the heavier soils in drier areas, drilling on the flat allows better preservation of the frost mould or tilth. Flat drilling also avoids an excessive drying out of the soil on lighter lands.

Using Graded Seed

The success of precision seeding depends on the use of seeds of the correct size, and therefore grading of seed to a uniform size, within small tolerances, is necessary. Using ungraded seed results in a very irregular and gappy braird, for if the seed is too large it will block the seeding holes of the drill, and if it is too small, it will pass through the holes two at a time.

Seedsmen specializing in the production of graded seed appear to be working closely with manufacturers of precision drills for, in addition to a declaration of seed size, they give the appropriate drill operation details for some of the best-known makes. Examples of the range in seed size adopted at two well-known seed houses are: .070-.076 in. and .067-.077 in. Seed for grading is usually selected from stocks with the highest percentage germination and the best energy of germination. This ensures a regular and strongly-growing braird in the field.

Protection of Seed and Seedlings from Pests and Diseases

Since the principle underlying the practice of precision seeding demands that each single seed germinates and grows into a healthy plant, it is of paramount importance that the seed should be protected from the pests and diseases which beset it during its early stage of growth. This is achieved by dressing the seed with a dual purpose insecticide/fungicide material which contains a high percentage of gamma-BHC as well as thiram. Each seed must carry its own load of protective material, and even after dressing a close watch must be kept on the seedlings in case subsequent spraying against pests is needed.

Efficient Drilling

Seeder units are independently mounted on the tractor toolbar and sowing may be either on the "ridge" or on the "flat". For ridge sowing, rolling with a flat roller is necessary before drilling since the drive is usually taken from the wheel running on or

near the seeding line. If there are a lot of stones, a fixed covering coulter on the drill is a disadvantage and should be replaced with a two-part staggered covering unit or a chain drag.

A steerage fin attached to the toolbar is recommended for drilling on the flat because the path it cuts remains as an accurate guide to the location of the rows, enabling inter-row mechanical hoeing to start before the plants emerge. The machine should not be used for flat drilling if stones are numerous.

Influence of Spacing on Yield of Crop and Root Size

Within reasonable limits, plant spacing has little influence on the total yield. The fact has been established that up to a spacing distance of about 7 in. between the plants, yields per acre are very little different from yields of crops sown and singled in the traditional manner. Experience in the higher rainfall areas suggests that a sensible space setting for the drill is 4 to 5 in. under near-ideal conditions of freedom from weeds, soil fertility and fertilizer treatment. With this setting plants will appear at 6 to 7 in. apart, irrespective of speed of travel. However, until the individual farmer has acquired some experience of the new technique, an initial spacing of 2 to 3 in. between the plants has much to recommend it. In the lower rainfall areas it may also be necessary to drill for 2 to 3 in. plant spacings to obtain a sufficiently regular braird.

The average size of root in plants spaced 7 in. apart is smaller than in a wider-spaced crop, but frost resistance is better. Resistance to frost damage is also greater in a precision-drilled crop due to a higher proportion of the "root" being in the soil. Against this benefit, however, is the higher percentage of wastage that occurs where crops are consumed *in situ*.

The Problem of Weeds

Closer plant spacing is advisable if weeds are likely. Where plants are spaced at 3 in., one plant in two has generally to be singled out. Singling and fairly satisfactory interplant weeding may be done with a mechanical gapper, but this should not be used on more widely-spaced plants as it could over-reduce plant population and adversely affect yield. In the absence of a gapping machine, mechanical inter-row hoeing should be started as soon as weeds begin to appear. The discs and/or blades of the machine can be set to cut in close proximity to the plants in the row as the absence of overcrowding means a "narrower" braird. This possible adjustment will help reduce the costs of weeding.

Experimental work in Wales has shown promising results with the use of pentachlorphenol (PCP) as a pre-emergence spray. Correct timing of the operation is vitally important. The crop is drilled in the weedy seedbed and spraying carried out a day or two later. Care must always be taken to prevent the machine causing too much soil disturbance.

Effect of Precision Seeding on Costs of Production

The benefits of precision seeding are:

1. a direct saving in seed and labour costs, and
2. elimination of the critical need for singling at any one time thus allowing urgent farm operations to proceed.

The usual quantity of seed required for 6 to 7 in. plant spacing is about ½ lb/acre, whilst under the normal method 3 to 4 lb are usual, even though many drills can be calibrated to sow as little as 1-1½ lb per acre. This in itself means a saving in costs, despite the fact that graded seed is twice the price of ungraded.

Culpin* assesses the total annual charge for the smaller farm on a £100 drill to be £12 10*s*. (i.e., depreciation, interest on capital, storage and general maintenance). This is a sum that can be easily balanced by savings in labour costs. A figure of £8 per acre for the cost of hand hoeing and singling a traditionally grown crop to a distance of 9 in. is a good general estimate; this cost in a crop precision drilled at 2 to 3 in. spacing is about £2 10*s*., which means a saving of £5 10*s*. per acre. Thus, where a drill is used to sow 2 acres in any year, the saving in costs just about covers the annual charge. Moreover, where the technique has become well understood, labour costs for hand hoeing and singling may be completely eliminated.

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*C. Culpin. *Agricultural Review*, 1958, **4**, 2.

Barn Drying of Baled Hay

C. CULPIN

Chief Machinery Adviser, National Agricultural Advisory Service

THE 1958 SEASON once more demonstrated how few British farmers have a system of haymaking that is capable of preserving a reasonable proportion of the nutrients contained in their crops. Perfect haymaking weather, as in 1957, can only be expected once or twice in a lifetime, and methods more suited to our variable climate must be developed, or the practice of haymaking abandoned. Indeed many farmers in 1958 changed their minds half-way through haymaking, and salvaged the crop on many thousands of acres by ensiling in clamps. However, silage is not necessarily the best method of conserving the whole of the grass crop, and a keen interest is now developing in improved haymaking methods.

A technique that could eventually play an important part in ensuring the production every year of a certain amount of high quality hay is barn hay drying, and now that this method can be applied to previously baled hay it is worth while to consider the possibilities and limitations of this method. Shepperson [1] has made a comprehensive review of the literature, in which the following introductory points are briefly made:

(*a*) Climatic factors often make it difficult to reduce the moisture content of hay to a safe storage level in the swath in under 3–4 days.

(*b*) Complete drying in the swath inevitably causes considerable loss of leaf, especially in leguminous crops, and this leaf is the most valuable part of the crop.

(*c*) Loading of the crop on to racks or tripods can secure appreciable improvements over drying in the swath, but has some disadvantages, especially as regards labour needed.

(*d*) Barn drying of loose hay can produce very satisfactory results, but handling small batches and loading the drier sometimes present difficulties.

The inevitable conclusion is reached that one of the most attractive systems of haymaking is to reduce moisture as rapidly as possible in the swath, bale the crop at an early stage, before leaf losses are appreciable, and complete the drying of the bales under cover. Successful barn drying of baled hay depends on many things, which can be briefly considered under the following main headings:

1. The objective must be reasonable and must take full account of various inescapable physical and economic factors.
2. Good, timely field work is essential.
3. The design of the plant must be suitable.
4. Care must be exercised in loading and operating the drier.

Reasonable Objectives

A new Ministry leaflet [2] explains in simple language the technical and economic importance of removing as much water as possible in the field. A table showing the weight of water that must be removed to produce a ton of dry hay shows that 1 ton of water has to be driven off to produce a ton of hay if the crop is taken in at 60 per cent moisture, whereas only 5 cwt of water has to be removed if the moisture content is reduced to 35 per cent in the field. It is pointed out that the highest practicable air speeds achieved in barn hay driers are low compared with even a gentle, natural breeze.

In practice, Shepperson [3] has shown that it is possible, though difficult, to dry baled hay containing as much as 60 per cent moisture; but this is inevitably very expensive, and may take far too long. There is no doubt that a more sensible objective is to reduce moisture content in the swath to 35-45 per cent. At this moisture content a typical medium density baler with a bale chamber 18 in. × 14 in. should be set so that a 3 ft-long bale weighs about 60-70 lb. Bales of moderate moisture content do not usually cause difficulty by falling to pieces after drying.

Some reports which have been made of bales of high moisture content being dried in a very short time must be ignored. Few practical all-electric plants are better equipped to dry rapidly than that used by Shepperson [3], and with this plant the drying times for batches ranging from 4½ ft to 9 ft deep ranged from 66 to 200 hours. With a 6 ft loading depth and reasonable moisture contents a one-week cycle should usually be attainable.

Good Field Work Essential

Many studies at N.I.A.E. [4] and elsewhere have proved beyond reasonable doubt that drying rate can be speeded up by early and effective tedding of the swaths, and that whether the objective is barn drying, tripod haymaking or field haymaking with a pick-up baler, such early tedding should be a normal objective, only to be abandoned in unexpectedly adverse weather conditions. For barn drying of baled hay it is essential to avoid having wads of crop which have never been shaken out, and this means that tedding early and twice daily with a really effective machine should be the normal technique. It helps considerably to vary the length of bales according to moisture content. Bales about 30 in. long are handy for crops baled at 40-50 per cent m.c. Care must be taken to re-adjust bale tension to variations of moisture content [1]. For instance, failure to re-adjust tension after the slight increase in moisture content as dew falls can result in greatly increased bale density and a batch of bales with high resistance to air-flow.

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BARN DRYING OF BALED HAY (See pp.[redacted])

C. Culpin

General view of a specially constructed 3-bay drier with a mobile heater which can be attached to any of the three fan units.

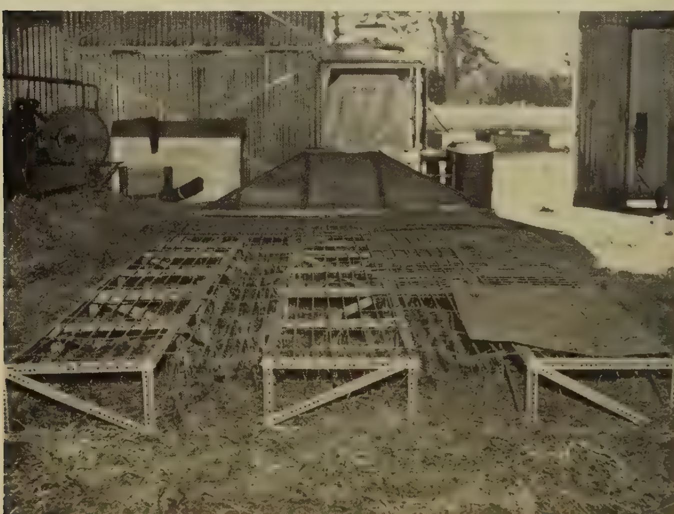
C. Culpin

Close-up of a mobile heater bank, mounted on castor wheels for easy movement.

PLATE I

National Institute of Agricultural Engineering

Mobile oil-fired heat exchanger ventilating unit drying a tall tunnel of bales built under a Dutch barn on a triangular framework.



National Institute of Agricultural Engineering

Recent investigations show that a low, wide tunnel is easier to build and gives more uniform drying than a high, narrow one. Welded metal reinforcing material is spread over the portable frames, which can be home-made. A specially constructed expansion piece is used here to connect the ventilating unit with the drying floor.

Plant Design

One of the most important details of design concerns air flow and resistance. Most of Shepperson's findings [5] agree with the results of American work [1]. The broad conclusion that may be drawn is that for a reasonably rapid rate of drying, air speeds of 45 ft/min through the crop should be provided by means of fans capable of working efficiently at static pressures up to 2½ in. water gauge.

There is still some room for differences of opinion on how much warm air is needed and the best way of providing it. With all-electric plants it is certain that heat must be used sparingly, since in most normal conditions, a given amount of drying can usually be done more economically by using unheated air than by warming the air electrically. However, it is an advantage to be able to warm a relatively low rate of air flow (15-20 ft/min) by 10-20°F at the finishing stage, and in practice modern all-electric installations are usually designed to produce high air flows (45-60 ft/min) which are used without heat in the early stages of drying, and low air flows (about 15 ft/min) which are used with heat for the final stage. Sufficient heater capacity is provided to warm the low air flow by 15-20°F [6]. (3 Kw. will warm 1,000 c.f.m. by approximately 10°F). A simple check will make farmers realize that little hay-drying capacity is provided by a typical ventilated silo grain drying plant.

Whether a well-designed plenum chamber and air-tight walls are required depends to a certain extent on the nature of the drying to be done. For hay baled at 45 per cent moisture or over there seems to be no satisfactory alternative to a specially designed plant, but limited experience shows that for crops baled at 35-40 per cent m.c. or below, "tunnel drying" can be effective [7].

For rapid "finishing" of fairly dry hay, American experience [8] shows the need for using heat, and oil-fired heat exchanger plants are generally used. Temperatures of 120° to 180°F at air flows of 25 ft/min are used. The performance of oil-fired heat exchangers [9] in Britain is being examined in practical conditions at Experimental Husbandry Farms, and results to date are generally satisfactory. A two-chamber method by which the air exhausted from a nearly dry batch is passed through a new batch has been developed in the U.S.A. to secure improved efficiency with batch driers using fairly high temperatures [10]. Batch weight is about 10 tons, and hay brought in at 40-50 per cent moisture can be dried in under two days, so that an output of 10 tons a day from two compartments is possible. Where a regular drying programme is contemplated, this type of arrangement may prove most attractive, whereas the tunnel method may be more suitable for conditioning large batches of hay baled at near to a safe storage moisture content. For the latter job, powerful old tractors driving large-capacity fans and warming the air by means of their waste heat may prove to be most economic.

Operation

Although published reports are not available, experience from the 1958 season has shown that bales need to be packed tightly into the drier to ensure that the air flows through the bales rather than through the spaces around them. This applies particularly to the upper layers. However, there is evidence that fairly loose packing of the first two layers in a bay or the inside layer in a tunnel gives satisfactory results.

Shepperson [3 and 5] has found some evidence in support of American advice that bales should be stacked with their cut edges downwards, rather than flat. With this method there is less tendency to damp spots beneath the bands. He finds that 4 layers of bales on edge—giving a hay depth of 6 ft—usually allows efficient drying, and suggests that where deeper layers must be dried, the first 6 ft should be nearly dried first and then additional layers added at no greater rate than 3-5 ft per day. Operators need to appreciate the relationship between airflow and resistance, and it is always essential to fit a simple manometer so that stalling of the fan can be avoided [2]. The problems involved in drying deep layers of bales have not yet been fully worked out, but it is clear that the convenience of the deep storage method is inevitably counterbalanced by relatively inefficient drying compared with the shallow batch method.

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Crop Husbandry Notes

C. KINSEY

National Agricultural Advisory Service, West Midland Region

The Effect of Nitrogen on Cereal Yields

Results of 270 experiments, a large proportion of which were conducted by the N.A.A.S. chiefly on commercial farms during the last decade, have been summarized and reported on by Bullen and Lessels (*Journal of Agricultural Science*, 1957, **49**, 319-28).

Response of Cereal Crops to a Standard Dressing of Nitrogen

The average responses of cereal crops to a standard dressing of 0.25 cwt/acre of nitrogen (or 1¼ cwt/acre sulphate of ammonia) were:

Crop	Number of Experiments	Response
		cwt/acre
Winter wheat . .	130	3.7
Spring wheat . .	51	3.3
Spring barley . .	39	4.2
Spring oats . . .	41	1.2
Winter oats . . .	9	4.1

Of the wheats, Hybrid 46 gave the highest response (4.9 cwt/acre) while Capelle and Nord Desprez, Bersée and Atle also did well. The stiff-strawed varieties of barley viz., Kenia, Proctor, Herta and Freja gave a greater response (5.8 cwt/acre) than did Plumage and Spratt Archer (3.5 cwt/acre). It is interesting to note that the average response (1.2 cwt/acre) of spring oats in 1945-55 is much lower than the 3.4 cwt/acre average response of the 86 experiments during 1900-40 examined by Crowther and Yates. There was no evidence of any regional variation in response of cereals to nitrogen apart from a tendency towards low responses in high rainfall areas.

Relative Responses to Early Spring, Late Spring and Split Nitrogen Dressings

The relative responses to nitrogen applied as an early, late spring and split dressing to spring barley and winter and spring wheat are given for 3 levels of application: up to 0.4 cwt N/acre, 0.4 to 0.8 cwt N/acre and more than 0.8 cwt N/acre. Although year to year and centre to centre variations were considerable, the results are nevertheless interesting:

	No. of Expts.	Grain Responses		
		Early	Late	½ early ½ late
		cwt/acre	*cwt/acre*	*cwt/acre*
Up to 0.4 cwt N/acre				
Winter wheat:				
March *v.* April applications .	13	3.9	3.6	
March / April *v.* May / early June applications . .	32	3.2	3.6	
Spring wheat and barley:				
Seedbed *v.* April applications	4	7.8	8.0	
Seedbed *v.* May/early June applications . . .	10	6.0	6.2	
0.4-0.8 cwt N/acre				
Winter wheat:				
March *v.* April applications .	5	10.9	11.3	11.2
March / April *v.* May / early June applications . .	10	8.3	5.9	8.5
Spring wheat and barley:				
Seedbed *v.* April applications	4	14.2	13.7	12.2
Seedbed *v.* May/early June applications . . .	11	9.7	7.5	9.6
More than 0.8 cwt N/acre				
Spring wheat and barley:				
March / April *v.* May / early June applications . .	5	15.3	11.8	14.7

Dressings of up to 0.4 cwt N/acre produced almost equal responses whether applied in March, April or May. For medium dressings (0.4-0.8 cwt N/acre) the results were nearly the same whether applied in March or April, but yields were about 2 cwt/acre less if the application was delayed until May.

Early applications of more than 0.8 cwt N/acre to spring wheat and barley produced 3½ cwt/acre more grain than when applied late.

With the medium and larger dressings (0.4 cwt N/acre and upwards) there was little yield difference whether the nitrogen was all applied early or half applied early and half late. However, the split dressing produced at least 2 cwt/acre more grain than the single dressing applied in May/June.

Autumn *v.* Spring Dressings of Nitrogen

The practice of applying nitrogen at seeding time to autumn-sown cereals has increased in recent years and is now common practice; surveys by Church in 1956 have shown that nearly one-third of the nitrogen applied to winter cereals is given in the seedbed. Reference is made to experiments conducted from 1884 to 1925 and analysed by

Cowie, who concluded that "the application of nitrogen in the seedbed cannot be recommended". On the other hand, in view of the current experiments being conducted by the N.A.A.S. on this matter, the authors' summary of some 17 experiments, in which a direct comparison was made between the effect of autumn and spring nitrogen, is of particular interest:

	Number of Experiments	Grain Yield		
		No N.	Autumn N.	Spring N.
		cwt/acre	*cwt/acre*	*cwt/acre*
Experiments showing no response to N. . .	3	24.5	24.9	24.1
Experiments with high winter rainfall . .	3	13.6	14.2	19.5
Other experiments . .	11	24.0	28.2	27.5
All experiments . .	17	22.2	25.2	25.5

Although the number of experiments are too few to allow final conclusions to be drawn, they show clearly the effect of high winter rainfall. The limited evidence also suggests that in the drier eastern counties reasonable applications of autumn nitrogen may give a response at least equal to a similar amount of nitrogen applied in spring.

Recommended Dressings of Nitrogen

Finally, the authors recommend the following dressings of nitrogen for cereals based on the 1956 standard prices of cereals and nitrogen at 85*s*. per cwt:

Crop	Response to Standard	Recommended Dressing	Net Return
	0.25 *cwt N/acre*	*cwt N/acre*	*shillings per acre*
Winter wheat:			
Hybrid 46 . . .	4.9	0.69	200
High responding varieties	4.5	0.65	117
Other varieties . .	3.1	0.51	100
Spring wheat . . .	3.3	0.53	111
Spring barley:			
Spratt and Plumage Archer . . .	3.5	0.50	97
High responding varieties	5.8	0.70	207
Spring oats . . .	2.0	0.28	30

It is emphasized that the above can only be an approximate guide to nitrogenous manuring, that the true optimal dressing varies from one centre to another, and that in the high rainfall areas such as Wales, the north-west and south-west of England, nitrogen should be used more sparingly.

The Effect of Seed Rate and Nitrogen on Lodging and Yield of Spring Barley

Although the harvesting difficulties caused by lodging are much less serious now that binders have been replaced by combine harvesters, its effect on yield and quality of grain merits attention. The experimental evidence also suggests that there is scope for the reduction of cereal seed rates on many farms. A paper on "The Effect of Seed Rate and Nitrogen on Lodging and Yield of Spring Barley" by MARY W. GLYNNE and W. B. SLOPE (*J. agric. Sci.*, 1957, **49,** 454-7) is therefore opportune.

The experiments were conducted at Rothamsted in 1954 and 1955 with Proctor barley. Seed rate treatments were 1, 2 and 3 bus./acre (R1, R2 and R3, each with 0 (in 1955 only), 1½, 3 and 4½ cwt/acre (N0, N1, N2 and N3) sulphate of ammonia applied in the seed bed. The July/August rainfall was 7.26 in. in 1954 and 1.06 in. in 1955 with about 70 per cent and 115 per cent of the 61 years' average hours of sunshine respectively in the two months.

Lodging

Although 92 per cent of the crop lodged in 1954 and only 19 per cent in 1955, the pattern of lodging was similar in both cases. The treatments had similar effects but differed in rate and extent of lodging. Increasing seed rates increased lodging; so did increased nitrogen, but it had less effect at the lower seed rate:

	Effect of Seed Rate and Nitrogen on Percentage Area Lodged											
	1954								1955			
	July					August			July			August
	5	8	15	22	30	6	13	25	7	18	25	17
	per cent								per cent			
Mean R1	0	2	3	21	46	69	83	90	0	0	1	3
,, R2	3	24	32	56	74	84	92	92	6	13	15	22
,, R3	14	30	43	71	84	88	91	95	9	18	24	32
Mean N1	0	2	2	18	47	64	74	84	0	0	0	3
,, N2	3	12	21	58	75	86	95	96	2	6	8	13
,, N3	13	42	55	71	82	92	97	97	13	25	32	42

Other experiments have shown that early lodging decreases yield and increases the proportion of shrivelled grain. In 1954, the year of most lodging, the date when half the crop was lodged was earlier in R3 compared with R1, by 8 days at N1, 14 days at N2 and 21 days at N3.

Although there were more plants per foot row in the heavier seeding rates, those in lowest seeding rate produced more tillers and ears per

plant. Nitrogen had no effect on plant population and except at N1 did not increase the number of ears.

In 1954 (the wet year) the treatment had no effects on crop height, but in 1955 the mean heights for R1, R2 and R3 were 42, 40 and 40 in. respectively, and for N0, N1, N2 and N3 they were 38, 40, 41 and 41 in.

The yield of straw was recorded in 1955. Added nitrogen had least effect on the lower seed rate but gave a steady increase in yield at the higher seed rates; N3 compared with N0 gave an extra straw yield of 5.1, 7.6 and 11.1 cwt/acre respectively for R1, R2 and R3.

Grain

The treatments had little effect on total grain yield in either year, but it is pointed out that the experiments were purposely sited on fertile land to increase the possibility of lodging. However, the size of grain was considerably affected; in 1955 R3 yielded 4.8 cwt/acre less of dressed grain than R1. Similarly, N3 yielded 6.3 cwt/acre less of dressed grain than N1 in 1954 and 7.1 cwt in 1955.

Nitrogen content of the grain in 1954 was only slightly affected by seed rate but was increased by nitrogen applications. Furthermore, it was highest in the smallest grain. The results are of particular interest to growers of malting barley:

Nitrogen Content of the Grain

R1	R2	R3	N1	N2	N3		R1 N1	R3 N3
	per cent			*per cent*			*per cent*	
1.94	1.92	1.91	1.79	1.93	2.05	Dressed . .	1.77	1.85
						Seconds . .	1.84	2.13
						Thirds . .	2.12	2.45

The authors conclude that when barley is grown for malting or seed, the lowest seed rate consistent with a good yield is especially desirable and that although 1 bus./acre may be too low for some conditions, 2 bus./acre is adequate for good conditions; this accords with Boyd's findings (*Emp. J. exper. Agric.*, 1952, **20**, 115-22).

The Influence of Depth of Soil Covering the Parent Tuber on the Development and Yields of the Potato Plant

Preliminary examination in 1953 and 1954 of some 3,000 random plants showed that yields and tuber numbers varied between 16 and 270 per cent of the mean values per plant. A series of trials were carried out at Sutton Bonington in 1955 and 1956 to determine the possible factors

causing this wide variation, and one aspect is reported on by Ivins and Montague in the *Empire Journal of Experimental Agriculture*, 1958, **26**, No. 101, 34-6.

King Edward and Ulster Prince tubers 1¾-2 in., planted 28×15 in. apart received differential soil coverage treatments at planting time with the following results:

Variety	King Edward						Ulster Prince			
Year	1955			1956			1955		1956	
Depth of soil cover (in.) .	1	4	7	1	4	7	1	6	1	4
Yield per acre (tons):										
Over 2¼ in.				1.4	2.4	2.1			5.4	8.4
2¼–1¾ in.				5.3	5.4	4.7			7.0	5.1
1¾–1¼ in.				3.2	2.4	2.1				
Under 1¼ in.				0.8	0.5	0.3			0.2	0.2
Total	11.1	11.1	9.6	10.7	10.7	9.2	15.6	14.3	12.6	13.7
No. of tubers per plant:										
Over 2¼ in.				0.7	1.3	1.2			1.5	2.2
2¼–1¾ in.				5.3	5.6	4.7			5.1	3.6
1¾–1¼ in.				6.8	5.0	4.3				
Under 1¼ in.				5.9	3.4	2.4			1.3	0.6
Total	27.0	17.5	15.1	18.7	15.3	12.6	15.2	10.8	7.9	6.4

The average number of tubers produced per plant increased with decreasing covering of soil, which also caused a slightly increased total yield, despite damage by frost in 1956. Deeper soil coverings delayed emergence, which may have accounted for the reduced yields.

The authors state that other workers have shown that tuber-set takes place early in the growth period of the plant, is partly governed by soil temperatures, and that increased tuber numbers resulting from shallow soil coverage may be due to fluctuating soil temperature and moisture content near the surface.

Contrasting varieties like King Edward and Ulster Prince, which produce a relatively large number of small tubers and a small number of large tubers respectively, present different problems to the ware and seed growers. The authors conclude that in addition to seed size and spacing, the above results suggest that the size composition of the crop may also be controlled by the depth of soil covering the tubers in the early stages of growth; subsequent earthing-up would, of course, be necessary if too high a proportion of green tubers is to be avoided.

Regional Note

Survey of Hill Sheep Flocks in Wales

W. R. SMITH

National Agricultural Advisory Service, Wales

Objects and Scope of the Survey

A SURVEY of hill sheep flocks in Wales was carried out by N.A.A.S. officers during the autumn and winter of 1956-57. The purpose of the enquiry was to collect information on the problems of low lambing percentage and the extent of the practice of hand feeding in hill flocks. Data given in the tables refer to the 1956 lamb crop year.

Table 1

Survey of Hill Sheep Flocks in Wales

SURVEY:				
638 flocks .	Subsidy—full rate	585	comprising 177,577 ewes mated	91.7%
	half rate	53		8.3%
		638		
WALES:				
6,729 flocks .	Subsidy—full rate	5,721	comprising 1,167,685 ewes	1,027,924
	half rate	1,008		139,761
		6,729		1,167,685
Subsidy—full rate	85% of flocks		Subsidy—full rate	87%
half rate	15% of flocks		half rate	12%
PERCENTAGES:				
9.5% hill flocks were surveyed.			15% of hill sheep were surveyed.	

The survey included 638 flocks, most of which had been the subject

of hill sheep subsidy and were therefore hardy flocks in regular ages, grazing high land and normally pure bred. Almost 10 per cent of the flocks were surveyed representing 15 per cent of the total hill ewe population of Wales.

Flock Size

The average size of flock was 278 ewes. This is just above half of the minimum 500 which the Committee responsible for the mid-Wales Report regarded as a satisfactory economic unit. The small size of flocks in Wales is retarding investment in better fixed equipment for dipping and handling, because of the fairly high capital outlay in relation to the number of ewes. It would seem that some form of co-operation in the installation and use of improved equipment is perhaps one answer to the problem. Better facilities would lead to improved flock hygiene and husbandry which are fundamental to sound health of sheep flocks.

Analysis by Breed Type

No. of Flocks	Breed	*Percentage*
383	Welsh Mountain . .	60
125	South Wales Mountain .	20
82	Speckled-faced . .	13
26	Radnor and Radnor X .	7
22	Cheviot X Welsh . .	

Welsh Mountain flocks were of the typical small, hardy, active breed grazing the mountain ranges of North Wales. South Wales Mountain sheep are bigger and popular in the industrial hill areas of Monmouth, Glamorgan, and parts of Brecon and Carmarthen. The Speckled-faced is the principal type in certain areas of mid-Wales, especially around Devil's Bridge. The Cheviot-Welsh type, which has been evolved by the occasional introduction of Cheviot rams into Welsh Mountain flocks, is mainly confined to an area in Brecon, and the Radnor and Radnor X may be found here and there in Brecon, Radnor and Monmouth.

The Hill Grazings

Forty per cent of the land of Wales lies over 800 ft above sea level. The herbage varies widely with *Nardus* and *Molinia* covering extensive areas of peat soils, but there are also better grazings of *Agrostis* and *Fescue*. Heather is not very common. Bracken is taking possession on some hill grazings, especially on the *Fescue* and *Agrostis* areas.

Statistical Summary of Survey

Table 2 gives the statistical story of the 638 flocks treated as a single unit.

Table 2

Analysis of Survey—Summary

	Number of farms—638 Average size of flock—278 ewes		
EWES:	Total number of ewes mated	177,577	*Percentage*
	Ewe deaths during pregnancy	5,271	2.90
	Number of ewes lambed (live or dead lambs)	150,999	85.10
	Ewe deaths after lambing	3,908	2.20
	Number of barren ewes	17,399	9.80
	TOTAL	177,577	100.00
LAMBS:			
	Lambs at summer count	145,235	
	% of ewes mated	81.7	

About 5 per cent of the ewes die every year for one reason or another, but in addition an average of 10 per cent are barren. An average of 10 per cent means that some flocks have more than this proportion of barren ewes, a situation about which flockmasters cannot be complacent. What is the explanation? It might be that too few rams are used or that apparently barren ewes have conceived but subsequently aborted during early pregnancy.

Perhaps the location of tupping, that is, whether on hill or inbye makes a difference, or is bad shepherding at this time responsible?

The ratio of rams to ewes is on average about 1:35, which is satisfactory, but on individual farms the ratio is much greater. In such cases shortage of rams might well be the reason for some barrenness, but generally good hill farmers attribute the trouble to bad shepherding at tupping time (provided rams are fertile). Certainly it is quite clear from survey reports that where shepherding is good, about 5 per cent only of ewes do not produce lambs. Furthermore, the Welsh ewe, like all hill breeds, is inherently fertile; it is the management of the ewe that seems to be at fault. In this connection, an analysis according to the location of tupping gave the barren ewe figure as 10 per cent for both hill and inbye.

The overall lambing percentage was found to be 81.7 (Table 2). This calculation is based on the number of lambs at the summer count, normally at shearing and the number of ewes put to the ram in autumn.

Enclosed and Common Hill Grazings

It is often said that standards of sheep husbandry are lower on farms with common grazings. A straight split of the 638 farms into "sole users" and "common users" gave the results shown in Table 3.

There was no significant difference in the number of lambs reared per 100 ewes, but no provision was made in the survey to provide information on the growth and quality of the two groups. One would expect the advantage to be with flocks on enclosed hills.

Table 3

Straight split of 638 farms into two groups—(1) Sole users of hill grazings.
(2) Common users of hill grazings.

	SOLE USERS		COMMON USERS	
Number of farms	341		297	
Average size of flock	340 ewes		209 ewes	
Number of ewes mated	115,509	*Percentage*	62,068	*Percentage*
Ewe deaths during pregnancy	2,998	2.60	2,273	3.60
Number of ewes lambed	97,838	84.50	53,161	85.60
Ewe deaths after lambing	2,435	2.40	1,473	2.40
Number of barren ewes	12,238	10.50	5,161	8.40
	115,509	100.00	62,068	100.00
Lambs at summer count	94,214		51,021	
% of ewes mated	81.5		82.2	

Supplementary Feeding of Hill Flocks

Feeding practice was examined on the 638 farms and divided in the analysis given in Table 4 below as follows:

(*a*) feeding with supplementary food standard practice in winter, especially in late pregnancy, or

(*b*) feeding not regular practice, except in times of emergency—snowstorms or hard frost.

The survey showed that supplementary feeding takes different forms, according to district and type of ewes. In general, the small North-Wales ewe is given very little help, except for a little hay in winter, but the bigger more productive ewes in South Wales, notably in Brecon and Radnor are wintered on roots at a stocking rate of about 50 ewes to one acre. Some flocks are given a little cereal, a few are fed a concentrate in nut form, and a small minority receive silage.

Table 4

Feeding

(1) Fed as a regular practice with hay, concentrates, cereals, silage, roots:
205 farms representing
35,257 ewes mated, or 19%
Lambs at summer count . . 30,550 or 87% of ewes mated.

(2) Feeding not a regular practice (only in emergency, e.g., storms):
433 farms representing
142,320 ewes mated, or 81%
Lambs at summer count . . 114,685 or 80% of ewes mated.

On 205 farms winter feeding was regarded as important, and the lambing rate was shown to be 87 per cent compared with 80 per cent on 433 farms not feeding as a regular practice. It must be noted that the year 1955-56 was favourable climatically all through, and one would therefore expect reduced response to hand feeding.

Opinion on the advisability of hand feeding is divided. The prejudice against it is fairly strong, but it cannot be denied that some ewes, if not all, will need food in times of stress, for example in late pregnancy when natural herbage is extremely scarce. The hill ewe has the ability to search for and exist on herbage growing on poor high ground. This is the quality she possesses which makes her superior to other ewes for these particular conditions. But if deprived of food for one reason or another, she is little better than any other ewe and supplementary food is then necessary. The problem facing advisory officers is that of overcoming the prejudice of many hill farmers against feeding any food whatsoever at any time.

Table 5 divides the farms according to location of tupping and feeding practice, reflecting in fact the various types of farms.

Group 1—a small number of farms mainly in South Wales, with good hills, keeping bigger ewes and providing roots, some cereal and hay in winter.

Group 2—farms with limited inbye land in relation to the hill area; normally the only home-grown food available is hay.

Group 3—farms mainly in South Wales with an adequate acreage of inbye land for wintering and for provision of winter fodder.

Group 4—a large group of farms almost all in North Wales with some enclosed grassland, but little or no fodder crops apart from hay.

Table 5
Location of Tupping

Management	Number of Flocks	Number of Ewes Mated	No. of Lambs at Count	Lambing Percentage
1. Tupped on mountain and feeding regular practice in late pregnancy	30	5,525	4,820	87
2. Tupped on mountain but *not fed* as regular practice	128	54,005	41,275	76
3. Tupped inbye, and feeding regular practice in late pregnancy . .	175	29,732	25,730	86.5
4. Tupped inbye, but *not fed* as a regular practice	305	88,315	73,410	83
SUMMARY: TUPPED ON MOUNTAIN .	158	59,530	46,095	77
TUPPED INBYE . .	480	118,047	99,140	84

The advantage of "kinder farms" and supplementary feeding are reflected in the higher lambing rates in groups 1 and 3. The lower

lambing percentage especially in group 2, is due to greater lamb mortality and not to any greater degree of barrenness in these flocks. The straight division of flocks according to location of tupping (mountain or inbye) shows an advantage in lambing percentage in favour of inbye, but again this is due to lower lamb mortality on what are obviously more favourable farms.

Age of Draft Ewes

The survey revealed that most ewes are drafted at 4½ years old, that is, after they have had three crops of lambs. Some are drafted a year earlier, and only exceptionally are they retained as five- or six-year-old ewes. It is well known that mature ewes normally rear more and better lambs than younger ewes. On the other hand, youth is an asset in difficult winters on hill farms, and the younger draft ewe has a higher market value. Nevertheless, it seems desirable that the question of age of drafting should be examined. If drafting as 5½-year-old ewes should prove practicable in Wales, there would be a wider selection of ewe lambs and shearlings than is possible now. However, one cannot generalize on this subject for practice must vary from farm to farm, or district by district, according to conditions.

Management of Ewe Lambs in Winter

Tables 6 and 7 show the pattern of management of ewe lambs. The ratio of ewe lambs to ewes is 1:3 (approx).) Of these, 37½ per cent were home wintered, and 62½ per cent were wintered away. Losses were about 4 per cent.

Table 6

Management of Ewe Lambs on the 638 Farms in Survey

63,456 lambs were wintered (home and away) related to 177,577 ewes mated, or 1 lamb to less than 3 ewes, or 35%

Home wintered—24,055 (37½%) Away wintered—39,401 (62½%)

Total—63,456.

Deaths—2,497 (just below 4%)

Ewe lambs given chance of ram— 7,659 or 12%

Ewe lambs shorn —25,222 or 40%

Work carried out by University College of North Wales, Bangor, has shown that ewe lambs wintered well will show a higher conception rate, yield better wool and as shearlings rear better lambs. Since two-thirds of the ewe lambs are wintered away, the importance of good winter grazing hardly needs emphasis, but unfortunately the quality of winter "tack" varies greatly. Some grazings will improve liveweight between autumn and spring by five, ten or more pounds per lamb. Other grazings will merely maintain autumn weight and the worst will show liveweight losses. The quality of "tack" may vary widely but these days the cost is uniformly high being around 30*s*. to 35*s*. per head.

Table 7

The farms were split according to location of tupping of ewes (see Table 5) which is in effect an indication of type of farm. The management of ewe lambs, i.e., home or away, is given for these four groups.

Management	No. of Farms	Home	Away	Deaths	Ewe Lambs Mated	Ewe Lambs Shorn
Ewe flock tupped on mountain and fed in winter.	30	1,859 (85%)	323 (15%)	122 (5½%)	584 (26%)	1,820 (83%)
Ewe flock tupped on mountain and not fed.	120	5,697 (32½%)	11,846 (67½%)	841 (4.75%)	2,210 (12.5%)	9,068 (50%)
Ewe flock tupped in-bye and fed in winter.	175	7,061 (60%)	4,645 (40%)	506 (4.3%)	2,427 (21%)	6,853 (58%)
Ewe flock tupped in-bye and not fed.	305	9,438 (29½%)	22,587 (70½%)	988 (3%)	2,438 (7.5%)	7,481 (23%)

It will be seen from Table 7 above that farms which are able to provide winter keep are wintering more lambs at home, and from discussions with the farmers at about half the cost of away wintering. The methods of home wintering practised vary, but can be listed as follows:

(*a*) on enclosed grassland or "ffridd" with hay supplement, and in some cases concentrate or cereal in addition;

(*b*) indoor wintering and hay feeding in sheds with outrun on restricted grazing (a system only developing);

(*c*) on foggage prepared for the purpose;

(*d*) on brassicae—Canson kale (with some swedes) with run back to restricted pasture.

Discussion with farmers in the survey showed that the quality of hay is vital, and when poor, ewe lambs winter badly unless a small amount of concentrate or cereal supplement is fed. Foggage will winter lambs very satisfactorily and show liveweight gain, but the low stocking rate of 6-8 head per acre is against the method. Brassicae, in the form of Canson kale with some swedes provide keep for 30 or more per acre, but in a late season the time-lag between the finish of the kale and growth of grass leads to loss of weight unless alternative food is given.

About 12 per cent of hill ewe lambs are put to the ram. Table 7 shows the practice to be more common, as one would expect, on the more favoured hill farms, where lambs are well grown. In most cases lambs are mated a month later than ewes.

Survey reports show wide variation in lambing percentage of from 20-75 per cent. It is surprising to learn that 40 per cent of ewe lambs

are shorn, normally at the same time as the ewe flock. Shearing of lambs used to reduce the incidence of blow-fly strike, but in these days with the use of effective dips, there seems to be no special virtue in the practice. Recent trials in Wales have confirmed this view.

Summary

The important findings of the survey were:

1. 5 per cent of ewes died, 10 per cent were barren and the overall lambing percentage was just over 80 per cent in a favourable year.
2. Supplementary feeding appeared to improve lambing percentage by 7-10 per cent in a favourable year.
3. One ram was used on average for 35-40 ewes.
4. Location of tupping did not appear to affect the percentage of barren ewes.
5. Lamb mortality was responsible for low lambing percentages on certain groups of farms.
6. Ewes are drafted after 3 crops of lambs, i.e., at 4½ years old.
7. Of the two-thirds of ewe lambs wintered away, and one-third at home, 4 per cent were lost through death, 12 per cent were put to the ram in their first year, and 40 per cent were shorn as lambs.

The Future

Such is the importance of hill sheep farming in Wales that the subject is demanding increased attention from N.A.A.S. officers. The survey clearly indicates those problems which require further investigation. It also forms a basis on which future technical work in this field may be planned.

The N.A.A.S. in Wales has at its disposal the benefit of the experience and results of investigational work on Welsh Mountain Sheep at Trawscoed, at Bangor and now at Pwllpeiran, as well as from elsewhere. In addition, officers in the field are conducting trials on the supplementary feeding of hill ewes, the wintering of ewe lambs on foggage and on brassicae, the shearing of ewe lambs, as well as collaborating with the veterinary service in trace element investigations. Present and future survey work is designed to examine the husbandry practices of the best men in hill farming. This practical and technical information will be of immense value to N.A.A.S. officers in their programme of advisory work amongst hill farmers in Wales.

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